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In re Patent Application of)
ÅKE JÖSTLUND, et al.) Group Art Unit: N/A
Application No.: 09/652,028) Examiner: Henry Tsai
Filed: August 31, 2000)
For: COATED MILLING INSERT)
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CLAIM FOR CONVENTION PRIORITY

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

The benefit of the filing date of the following prior foreign application in the following foreign country is hereby requested, and the right of priority provided in 35 U.S.C. § 119 is hereby claimed:

Swedish Patent Application No. 9903090-0

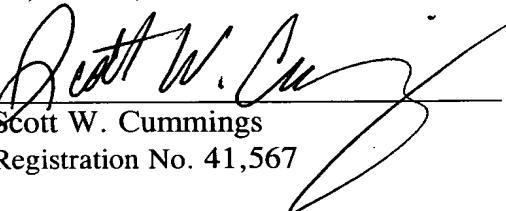
Filed: September 1, 1999

In support of this claim, enclosed is a certified copy of said prior foreign application. Said prior foreign application was referred to in the oath or declaration. Acknowledgment of receipt of the certified copy is requested.

Respectfully submitted,

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Patentavdelningen

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Coated milling insert

The present invention relates to a coated cemented carbide cutting tool (indexable insert) for milling, particularly useful for milling at high cutting speeds in low and medium alloyed steels or milling in hardened steels at high cutting speed, preferable at dry and rather stable conditions, but also for milling in cast iron and some of the stainless steels at high cutting speed.

It is well known that for cemented carbide cutting tools used in the machining of steels, the cutting edge is worn by different wear mechanisms such as chemical and abrasive wear but the tool edge may also fracture under a heavy intermittent cutting load, resulting in so called edge chipping which is usually initiated by cracks formed perpendicular to the cutting edge. This type of cracks is named comb cracks. Furthermore, different cutting conditions such as cutting speed, depth of cut, cutting feed rate and also external conditions such as dry or wet machining, vibrations of the work piece, or a surface zone from forging or casting on the work piece, or milling in hardened steels etc., require a plurality of different properties of the cutting edge.

For instance, when milling in a medium alloyed steel where the surface of the work piece material is covered by a so called surface skin containing areas with high hardness, obtained from casting or forging, a coated cemented carbide insert must be used including a substrate of a tough cemented carbide grade and on the surface a wear resistant refractory coating is deposited. When applying a coated carbide cutting insert in milling of a workpiece of a low alloyed steel or a austenitic stainless steel at high cutting speeds, adhesive forces between the chip and the cutting edge will occur causing chipping along the cutting edge. In addition when milling in ordinary low or medium alloyed steels at very high cutting speeds, the thermal energy developed in the cutting zone is considerable and the entire tool edge may plastically deform independent of the type of coating used. The meaning of high cutting speed is dependent of the properties of the work piece material and other factors related to the cutting operation. High cutting speed is the upper speed range that normally could be found at the work shops. Furthermore when milling in hardened steels, hardened to at least 300 Brinell but

often above 400-500 Brinell, the mechanical loads obtained normally reduces the tool life by fracture of the tool. When milling in hardened steels at high cutting speed, high mechanical load is obtained in combination with high temperature at the cutting zone, which normally reduces the tool life rather drastically.

Commercial cemented carbide tools for milling in steel, stainless steel or cast iron, at high cutting speeds, are usually optimized with respect to one or two of the wear types observed.

Swedish patent application 9501286-0 discloses a coated cutting insert particularly useful for dry milling of grey cast iron. Swedish patent application 9502640-7 discloses a coated turning insert particularly useful for intermittent turning in low alloyed steel.

In WO 97/20083 is disclosed a coated cemented carbide cutting tool particularly designed for the wet and dry milling of workpieces of low and medium alloyed steels or stainless steels, with or without abrasive surface zones, in machining operations requiring a high degree of toughness of the carbide cutting edge. The external cutting conditions are characterized by complex shapes of the workpiece, vibrations, chip hammering, recutting of the chips etc.

In WO 97/20081 is disclosed a coated cemented carbide cutting tool particularly designed for the wet and dry milling of low and medium alloyed steels.

It has now surprisingly been found that by combining many different features a cutting tool, preferably for milling, can be obtained with excellent cutting performance in low and medium alloyed steels at high cutting speed, as well as milling in hardened steels at high cutting speed, in work piece materials with or without abrasive surface zones preferably under stable and dry conditions. It has also been found that this specific cutting tool also works in cast iron and stainless steel at high cutting speed. The cutting tool according to the invention shows improved properties with respect to the different wear types prevailing at these cutting conditions as earlier mentioned.

The cutting tool insert according to the invention consists of: a cemented carbide body with a rather high W-alloyed binder phase and with a well balanced chemical composition and grain size of the WC, a columnar $TiC_xN_yO_z$ -layer, a $\kappa-Al_2O_3$ -layer, a TiN-layer and

optionally followed by smoothening the cutting edges by brushing the edges with e.g. a SiC based brush.

According to the present invention a coated cutting tool insert is provided consisting of a cemented carbide body with a composition of 7.1-7.9 wt% Co, preferably 7.3-7.9 wt% Co, most preferably 7.4-7.8 wt% Co, 0.2-1.8 wt% cubic carbides, preferably 0.4-1.8 wt% cubic carbides, most preferably 0.5-1.7 wt% cubic carbides of the metals Ta, Nb and Ti and balance is made up by WC. The cemented carbide may also contain other carbides from elements from group IVb, Vb or VIb of the periodic table. The content of Ti is preferably on a level corresponding to a technical impurity. The average grain size of the WC is in the range of about 1.5-2.2 μm , preferably about 1.8 μm .

The cobalt binder phase is rather high alloyed with W. The content of W in the binder phase can be expressed as the CW-ratio= $M_S / (\text{wt\% Co} \cdot 0.0161)$, where M_S is the measured saturation magnetization of the cemented carbide body in kA/m and wt% Co is the weight percentage of Co in the cemented carbide. The CW-value is a function of the W content in the Co binder phase. A high CW-value corresponds to a low W-content in the binder phase.

It has now been found according to the present invention that improved cutting performance is achieved if the cemented carbide body has a CW-ratio of 0.85-0.96, preferably 0.86-0.94, and most preferably 0.86-0.93. The cemented carbide may contain small amounts, <1 volume %, of η -phase (M_6C), without any detrimental effect. From the CW-value it follows that no free graphite is allowed in the cemented carbide body according to the present invention.

The coating comprises

- a first (innermost) layer of $\text{TiC}_x\text{N}_y\text{O}_z$ with $x+y+z=1$, preferably $y>x$ and $z<0.2$, most preferably $y>0.8$ and $z=0$, with equiaxed grains with size <0.5 μm and a total thickness <1.5 μm preferably >0.1 μm .
- a layer of $\text{TiC}_x\text{N}_y\text{O}_z$ with $x+y+z=1$, preferably with $z=0$, $x>0.3$ and $y>0.3$, most preferably $x>0.5$, with a thickness of 1-8 μm , preferably 2-7 μm , most preferably <6 μm , with columnar grains and with an average diameter of <5 μm , preferably 0.1-2 μm
- a layer of a smooth, fine-grained (grain size about 0.5-2 μm) Al_2O_3 consisting essentially of the κ -phase. However, the layer may contain small amounts, 1-3 vol-%, of the θ - or the α -phases as de-

5 determined by XRD-measurement. The Al_2O_3 -layer has a thickness of 0.5-5 μm , preferably 0.5-2 μm , and most preferably 0.5-1.5 μm . Preferably, this Al_2O_3 -layer is followed by a further layer (<1 μm , preferably 0.1-0.5 μm thick) of $\text{TiC}_x\text{N}_y\text{O}_z$ with $x+y+z=1$, preferably with $y > x$ and $z < 0.3$, most preferable $y > 0.8$, but the Al_2O_3 layer can be the outermost layer. This outermost layer, Al_2O_3 or $\text{TiC}_x\text{N}_y\text{O}_z$, has a surface roughness $R_{\text{max}} \leq 0.4 \mu\text{m}$ over a length of 10 μm . The $\text{TiC}_x\text{N}_y\text{O}_z$ -layer, if present, is preferably removed along the cutting edge. Alternatively, the $\text{TiC}_x\text{N}_y\text{O}_z$ layer is removed and the underlying alumina layer is partly or completely removed along the cutting edge.

The present invention also relates to a method of making a coated cutting tool insert consisting of a cemented carbide body with a composition of 7.1-7.9 wt% Co, preferably 7.3-7.9 wt% Co, most preferably 7.4-7.8 wt% Co, 0.2-1.8 wt% cubic carbides, preferably 0.4-1.8 wt% cubic carbides, most preferably 0.5-1.7 wt% cubic carbides of the metals Ta, Nb and Ti and balance WC. The cemented carbide may also contain other carbides from elements from group IVb, Vb or VIb of the periodic table. The content of Ti is preferably on a level corresponding to a technical impurity. The average grain size of the WC is in the range of about 1.5-2.5 μm , preferably about 1.8 μm . Onto the cemented carbide body is deposited

25 - a first (innermost) layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably $y>x$ and $z<0.2$, most preferably $y>0.8$ and $z=0$, with equiaxed grains with size $<0.5 \mu m$ and a total thickness $<1.5 \mu m$, preferably $>0.1 \mu m$, using known CVD-methods.

- a layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably with $z=0$, $x>0.3$ and $y>0.3$, most preferably $x>0.5$, with a thickness of 1-8 μm , preferably 2-7 μm , most preferably <6 μm , with columnar grains and with an average diameter of about <5 μm , preferably 0.1-2 μm , using preferably MTCVD-technique (using acetonitrile as the carbon and nitrogen source for forming the layer in the temperature range of 700-900 $^{\circ}C$). The exact conditions, however, depend to a certain extent on the design of the equipment used.

- a smooth Al_2O_3 -layer essentially consisting of $\kappa\text{-Al}_2\text{O}_3$ is deposited under conditions disclosed in e.g. EP-A-523 021. The Al_2O_3 layer has a thickness of 0.5-5 μm , preferably 0.5-2 μm , and most preferably 0.5-1.5 μm . Preferably, a further layer (<1 μm , preferably 0.1-0.5 μm thick) of $\text{TiC}_x\text{N}_y\text{O}_z$ is deposited, but the Al_2O_3 -

layer can be the outermost layer. This outermost layer, Al_2O_3 or $\text{TiC}_x\text{N}_y\text{O}_z$, has a surface roughness $R_{\text{max}} \leq 0.4 \mu\text{m}$ over a length of 10 μm . The smooth coating surface can be obtained by a gentle wet-blasting the coating surface with fine grained (400-150 mesh) alumina powder or by brushing (preferably used when $\text{TiC}_x\text{N}_y\text{O}_z$ top coating is present) the edges with brushes based on e.g. SiC as disclosed e.g. in Swedish patent application 9402543-4. The $\text{TiC}_x\text{N}_y\text{O}_z$ -layer, if present, is preferably removed along the cutting edge. Alternatively, the $\text{TiC}_x\text{N}_y\text{O}_z$ layer is removed and the underlying alumina layer is partly or completely removed along the cutting edge.

Example 1.

A. A cemented carbide milling tool in accordance with the invention with the composition 7.6 wt-% Co, 1.22 wt-% TaC, 0.30 wt-% NbC and balance is made up by WC, with a binder phase alloyed with W corresponding to a CW-ratio of 0.87 were coated with a 0.5 μm equiaxed $\text{TiC}_{0.05}\text{N}_{0.95}$ -layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 4 μm thick $\text{TiC}_{0.54}\text{N}_{0.46}$ -layer, with columnar grains by using MTCVD-technique (temperature 885-850 $^{\circ}\text{C}$ and CH_3CN as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 1.0 μm thick layer of Al_2O_3 was deposited using a temperature 970 $^{\circ}\text{C}$ and a concentration of H_2S dopant of 0.4 % as disclosed in EP-A-523 021. A thin (0.3 μm) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the Al_2O_3 -layer consisted of 100 % κ -phase. The cemented carbide body had a WC grain size in average of 1.7 μm .

B. A cemented carbide milling tool with the composition 9.1 wt-% Co, 1.25 wt-% TaC, 0.30 wt-% NbC and the balance is made up by WC, with a binder phase alloyed with W corresponding to a CW-ratio of 0.90. The cemented carbide body had a WC grain size in average of 1.7 μm , and a similar coating compared to the coating on A, but the thickness of the Al_2O_3 -layer was 1.2 μm .

C. A cemented carbide milling tool with the composition 6.0 wt-% Co, and the balance is made up by WC, with a binder phase alloyed with W corresponding to a CW-ratio of 0.90, and a WC grain size is 1.8 μm . The coating is similar to the coating on A, but the thickness of the Al_2O_3 -layer was 4.1 μm and this layer is the outermost layer.

Operation: Face milling - semi finishing
Work-piece: Support ring
Material: SS 2242, hardened to 51 HRC
5 Cutting speed: 100 m/min
Feed rate/tooth: 0.09 mm/rev.
Depth of cut: 0.3-3.5 mm
Insert-style: RCKT 1606MO
Cutter-body: R200-084Q32-16M
10 Note: 6 inserts, dry and stable conditions

Results: Tool-life, (average value after 3 tests per variant) min:
Grade A: 24
15 Grade B: (prior art) 12
Grade C: (prior art) 14

Tool-life criteria were fracture on rake face of the inserts, and flake wear.
20

Example 2.

D. A cemented carbide milling tool in accordance with the invention with the composition 7.2 wt-% Co, 1.24 wt-% TaC, 0.29 wt-% NbC and balance WC, with a binder phase alloyed with W corresponding to a CW-ratio of 0.92 were coated with a 0.5 μm equiaxed $\text{TiC}_{0.05}\text{N}_{0.95}$ -layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 5 μm thick $\text{TiC}_{0.54}\text{N}_{0.46}$ -layer, with columnar grains by using MTCVD-technique (temperature 885-850 $^{\circ}\text{C}$ and CH_3CN as the carbon/nitrogen source).
25 In subsequent steps during the same coating cycle, a 1.5 μm thick layer of Al_2O_3 was deposited using a temperature 970 $^{\circ}\text{C}$ and a concentration of H_2S dopant of 0.4 % as disclosed in EP-A-523 021. A thin (0.3 μm) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the Al_2O_3 -layer
30 consisted of 100 % κ -phase. The cemented carbide body had a WC grain size in average of 1.8 μm .
35

E. A commercial cemented carbide cutting tool with the composition of 8.0 wt-% Co, 0.2 wt-% TiC, 1.8 wt-% TaC, 0.2 wt-% NbC, and balance is made up by WC, and CW-ratio of 0.85. The WC-

grain size was $1.7 \mu\text{m}$. The insert had a conventional CVD-coating consisting of total $4 \mu\text{m}$ TiC/TiC_xN/TiN.

Inserts from B, D and E were tested in a face milling operation.

Operation: Face milling

5 Work-piece: Bar, 300x200 mm (4 passages per 200 mm)

Material: SS2541, HB=300

Cutting speed: 367 m/min

Feed rate/tooth: 0,15 mm/rev.

10 Depth of cut: 2 mm

Insert-style: SEKN 1204

Note: 6 inserts, dry and stable condition

Results: Tool-life, milled length m, average
15 of two tests

Grade D: 9.0

Grade B: (prior art) 7.8

Grade E: (prior art) 5.7

20 Tool-life criteria were flank wear and chipping between comb cracks

Example 3.

Inserts from B and A were tested in face milling

25 Operation: Face milling - semi finishing

Work-piece: Axle housing

Material: cast steel low alloyed, HB=280

Cutting speed: 228 m/min

Feed rate/tooth: 0,24 mm/rev.

30 Depth of cut: 1.3-3.2 mm

Insert-style: LNCX 1806AZ R-11

Note: dry, 10 teeth, unstable tendencies

Results: Tool-life, number of component
35 per edge set

Grade A: 5

Grade B: (prior art) 1

Tool-life criterion was flank wear and plastic deformation.

Example 4.

Inserts from A and C were tested in face milling in a hardened plate with holes.

5

Operation: Face milling - roughing
 Work-piece: Plate, 300x220 mm
 Material: 1.2767, machined surface with holes, 54 HRC
 Cutting speed: 67 m/min
 Feed rate/tooth: 0.27 mm/rev.
 Depth of cut: 1 mm
 Insert-style: RCKT 1204
 Note: dry, 6 teeth, instability

15

Results:	Tool-life, no of passages, min	
Grade A:	18	13.5
Grade C: (prior art)	8	6

20

Tool-life criterion was flank wear and plastic deformation

Example 5.

F. A cemented carbide milling tool in accordance with the invention with the composition 7.2 wt-% Co, 1.24 wt-% TaC, 0.29 wt-% NbC and balance is made up by WC, with a binder phase alloyed with W corresponding to a CW-ratio of 0.89 were coated with a 0.5 μm equiaxed $\text{TiC}_{0.05}\text{N}_{0.95}$ -layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 4 μm thick $\text{TiC}_{0.54}\text{N}_{0.46}$ -layer, with columnar grains by using MTCVD-technique (temperature 885-850 $^{\circ}\text{C}$ and CH_3CN as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 1.0 μm thick layer of Al_2O_3 was deposited using a temperature 970 $^{\circ}\text{C}$ and a concentration of H_2S dopant of 0.4 % as disclosed in EP-A-523 021. A thin (0.3 μm) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the Al_2O_3 -layer consisted of 100 % κ -phase. The cemented carbide body had a WC grain size in average of 1.75 μm .

Inserts from F and B were tested in a face milling operation. A cutter body with a diameter of 160 mm were central positioned relatively a rod with a diameter of 90 mm.

40

Operation: Face milling
 Work-piece: SS2541 diameter 90 mm, HB=310
 Cutting speed: 372 m/min
 Feed rate/tooth: 0,32 mm/rev.
 5 Depth of cut: 2 mm
 Insert-style: R245 12T3E-PL
 Note: dry, one tooth

Results: Tool-life, (average 2 tests) min:
 10 Grade F : 13
 Grade B (prior art) : 9.5
 Tool-life criterion was chipping due to comb crack formation.

Example 6.

15 Inserts from A and B were tested in cavity milling with round inserts.

Operation: Cavity milling including ramping
 Work-piece: Orvar Supreme 41 HRC (AISI Prem.H13), 220x250 mm
 20 Cutting speed: 175 m/min
 Feed rate/tooth: 0,20 mm/rev.
 Depth of cut: 2 mm
 Insert-style: RCKT 1204
 Note: dry, some instability
 25

Results: Tool-life, (average 2 tests) min:
 Grade A: 60
 Grade B: (prior art) 21
 30 Tool-life criterion was chipping due to comb crack formation.

Example 7.

G. A commercial cemented carbide cutting tool with the composition of 7.0 wt-% Co, 0.1 wt-% TiC, 0.7 wt-% TaC, 0.1 wt-% NbC, and balance is made up by WC and CW-ratio of 0.90. The WC-grain size was 2.6 μm . The insert were coated with a 0.3 μm TiN-layer followed by a 0.8 μm thick Al_2O_3 -layer, followed by a 0.5 μm TiN-layer followed by a 4.3 μm TiC,N-layer by using MTCVD-technique and finally followed by a 0.2 μm TiN-layer.

Inserts from A, B and G were tested in cavity milling with round inserts.

Operation: Cavity milling including ramping

5 Work-piece: Nimax, 7 hardened to 390 HB, 220x250 mm

Cutting speed: 250 m/min

Feed rate/tooth: 0,27 mm/rev.

Depth of cut: 2 mm

Insert-style: RCKT 1204 and RPMT 1204

10 Note: dry, some instability

Results: Tool-life, min:

Grade A: 55.4

Grade B: (prior art) 32.0

15 Grade G: (prior art) 14.9

Tool-life criterion was chipping due to comb crack formation.

Claims

1. A cutting tool insert for milling low and medium alloyed steels with or without abrasive surfaces during dry or wet conditions at high cutting speed, and milling hardened steels at high cutting speed, comprising a cemented carbide body and a coating characterized in that said cemented carbide body comprises WC, 7.1-7.9 wt-% Co and 0.2-1.8 wt-% cubic carbides of Ta, Ti and Nb, with Ti present on a level corresponding to a technical impurity, and a highly W-alloyed binder phase with a CW-ratio of 0.85-0.96 and in that said coating comprises

- a first (innermost) layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably $z<0.5$, with a thickness of 0.1-1.5 μm , and with equiaxed grains with size $<0.5 \mu m$

15 - a layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably with $z=0$ and $x>0.3$ and $y>0.3$, with a thickness of 1-6 μm with columnar grains with a diameter of about $<5 \mu m$

20 - a layer of a smooth, fine-grained (0.5-2 μm) $\kappa-Al_2O_3$ with a thickness of 0.5-5 μm and

- preferably an outer layer of TiN with a thickness of $<1 \mu m$.

2. Milling insert according to claim 1

characterized in that the cemented carbide has the composition 7.4-7.8 wt-% Co and 0.4-1.8 wt-% carbides of Ta and Nb.

3. Milling insert according to any of the preceding claims characterized in a CW-ratio of 0.86-0.93.

25 4. Milling insert according to any of the preceding claims characterized in that the outermost TiN-layer, if present, has been removed along the cutting edge.

5. Method of making a milling insert comprising a cemented carbide body and a coating characterized in that WC-Co-based cemented carbide body with a highly W-alloyed binder phase with a CW-ratio of 0.85-0.96 is coated with

- a first (innermost) layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably $z<0.5$, with a thickness of 0.1-1.5 μm , with equiaxed grains with size $<0.5 \mu m$ using known CVD-methods

35 - a layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably with $z=0$ and $x>0.3$ and $y>0.3$, with a thickness of 1-6 μm with columnar grains with a diameter of about $<5 \mu m$ deposited by MTCVD-technique, using acetonitrile as the carbon and nitrogen source for forming the layer in a preferred temperature range of 850-900 $^{\circ}C$.

40 - a layer of a smooth $\kappa-Al_2O_3$ with a thickness of 0.5-5 μm and

- preferably a layer of TiN with a thickness of <1 μ m.
- 6. Method according to the previous claim characterized in that said cemented carbide body has a cobalt content of 7.4-7.8 wt% and 0.4-1.8 wt% cubic carbides of Ta and Nb.
- 5 7. Method according to any of the claims 5 and 6 characterized in a CW-ratio of 0.86-0.93.
- 8. Method according to any of the claims 5, 6 and 7 characterized in that the outermost TiN-layer, if present, is removed along the cutting edge.

Abstract

The present invention discloses a coated milling insert particularly useful for milling in low and medium alloyed steels with or without abrasive surface zones during dry or wet conditions at 5 high cutting speed, and milling hardened steels at high cutting speed. The insert is characterized by WC-Co cemented carbide with a low content of cubic carbides and a highly W-alloyed binder phase and a coating including an innermost layer of $TiC_xN_yO_z$ with columnar grains and a top layer of TiN and an inner layer of κ -
10 Al_2O_3 .